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Group Size and Composition of Black-and-White Snub-nosed Monkey (*Rhinopithecus bieti*) Estimated by Faeces of Sleeping Sites at Baima Snow Mountain

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Abstract: This study was designed to introduce a new method of estimating group size and composition of black-and-white snub-nosed monkeys (*Rhinopithecus bieti*) on the basis of faecal amount at sleeping sites at Mt. Baima Nature Reserve. The monkeys spend nights in the form of one-male, multi-female units (OMUs) and all-male units (AMU), and their faecal pellets can be classified into three categories: adult males (the largest), adult females (moderate) and immatures (the smallest) based on their size. Total pellets were counted under sleeping trees used for two nights at Nanren village (99°04′E, 28°34′N, northwest of Yunnan Province, China) in each of four seasons in 2000–2001. Moreover, data on group composition were collected when the monkeys were passing through an open gully in November 2001. Since the number of adults in OMUs shows a positive significant correlation with the amount of pellets amount in each season, the mean number of feces produced per night per individual is the slope of the regression lines. Thus, group size and composition can be relatively reliably and accurately estimated by the faeces under trees compared with the previous methods of estimation, including the use of monkeys' activities and tracks such as broken branches on steep slopes, in deep gorges and under lower visibility. The use of pellets for population estimates displayed 9.4% deviation in regards to population size of adult females. Some causes of the bias were also discussed. The method might be applicable to other monkey groups of this species if their habitats and main foods are similar to those of the study group.

Key words: Feces; Group composition; Group size; *Rhinopithecus bieti*; Sleeping site

利用过夜地粪便估计白马雪山黑白仰鼻猴种群大小和组成

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摘要: 介绍了应用过夜地粪便来估计白马雪山黑白仰鼻猴群大小和组成的一种方法。该物种以单雄多雌单元和全雄组的形式在树上过夜。粪粒根据其大小可分为3种类型: 成年雄性的(最大)、成年雌性的(中等大小)和未成年个体的(最小)。2000—2001年, 搜集了滇西北白马雪山国家级自然保护区北部南任村(99°04′E, 28°34′N)附近黑白仰鼻猴群每个季节2个过夜地的粪粒。根据2001年11月猴群通过开阔地的数据来确定猴群组成。每个季节, 由于单雄多雌单元的成年个体数与其粪粒数正相关, 所以二者回归直线的斜率可以看作是每个个体每晚的平均排便量。由于该物种的栖息地主要为高山峡谷, 而且能见度较低, 因此, 利用过夜地粪便比以前通过猴群活动痕迹来估计猴群大小和组成相对准确、可靠。从估计成年雌性个体数的角度看, 利用粪粒来估计种群大约有9.4%的偏差。导致偏差的可能原因有杂草和灌丛对粪粒准确计数的影响、个体排粪率的差异以及成年雄性最小粪粒与成年雌性最大粪粒的混淆等。该方法适应于栖息地和主要食物与本文研究种群相似的其他种群。

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Although Colobine monkeys show great diversities in their social organizations; which includes monogamy, matrilineal-harem, matrilineal-multi-male and patrilineal-multi-male; the modal pattern of social organizations appears to be one male, multi-female units (OMUs). In matrilineal societies, there are typically also all-male units or solitaries (Newton & Dunbar, 1994).

The percentage of OMUs in the band varies with the species in Colobinae, ranging from 66% in *Pygathrix nemaeus* (Lippold, 1977) to 100% in *Rhinopithecus brelichi* (Bleisch et al, 1993). There are wide variations in the number of adult females (AFs) in OMUs and the size of OMUs between species, as well as within groups of the same species. The extremes of OMU size range from 11－34 monkeys with only 4－12 AFs in *Presbytis entellus* (Newton, 1987) to 5－13 animals with 2－5 AFs in *P. pileata* (Stanford, 1991). The ratio of adult males (AMs) to AFs in OMUs also changed with species, ranging from 1.0∶2.7 in *Pygathrix nemaeus* (Lippold, 1977) to 1.0∶7.8 in *P. melalophos* (Bennett, 1983).

The study group of black-and-white snub-nosed monkeys (*Rhinopithecus bieti*) numbered 175 animals, and held 15－18 OMUs and one all-male unit (AMU) consisting of 13－15 individuals (Kirkpatrick, 1996). *Rhinopithecus bieti* mainly lives in fir forests with steep slopes and deep gorges, where the visibility is very low. The monkeys are also very shy of humans, so only five of 13 groups of *R. bieti* have been counted since 1979 (Xiao et al, 2004). Although other group sizes have been roughly estimated through the use of monkeys' activities and tracks such as broken branches and feces (Long et al, 1996), to some extent they were unreliable since there was not an inter-relationship between monkeys and their activities and tracks. In addition, *R. bieti* is subject to heavy pressure from habitat degradation and poaching, and as many as five groups, each of which numbered less than 50, have disappeared from their original sites in the past 10 years (Xiao et al, 2004). Thus, it is urgent and important that monitoring of population dynamics is refined to work towards preparing conservation plans for the species. Even if the monkeys can be followed, there are few chances to count them all due to the density of the forests. Fortunately, *R. bieti* spends nights in the form of OMUs and AMUs in trees, and sleeping sites are easily found compared with monkeys. In addition, the appearance and size of faecal pellets for the species are stable as those of sheep and goats (Zhao et al, 1988) and they are easily distinguished from other animals' faeces. Thus, this implies that the use of faecal sampling under sleeping trees has potential for estimating the population size.

1 Materirals and Methods

1.1 Study site

The study site is at Nanren (99°04′E, 28°34′N) on the east slope of Baima Snow Mountain, Southwest of Yunnan, China, within the northernmost range of the band of *R. bieti* studied by Kirkpatrick (1996). The vegetation is characterized by striking altitudinal zonation. In general, alpine meadows change into conifer forests at lower than 4 300 m, and these give way to oak forests at 3 800－3 600 m (Kirkpatrick, 1996). Oak shrubs are at altitudes lower than 3 600 m. Forests have been little disturbed except for selective logging on the winter slope, especially at lower altitudes. Total faecal pellets under sleeping trees were systematically sampled during the period from 10 to 25 April, 7 to 22 June, 20 September to 5 October, and 6 to 18 November in 2001.

1.2 Determination of sleeping sites

Sleeping sites can be determined when the monkeys are followed by visual observation, but can also be determined by the number of faecal patches and the characteristics of its distribution across their home range (Cui et al, 2006a). Monkeys spend nights in the trees in the form of OMUs and AMUs. This provides the possibility and convenience of making population estimates based on faecal pellets under trees. When the distance between two adjacent sleeping trees is longer than half of the sum of their crown diameters, they are considered as two sleeping trees. When the distance is under half of the sum of the crown diameters it is considered a sleeping-tree cluster.

1.3 Classification of faecal pellets

There is only one group of *R. bieti* in the study area, and *R. bieti* faeces look like abacus beads and easy to distinguish from the droppings of other animals. Pellet sizes of captive *R. bieti* positively correlate with animal size (Zhao et al, 1988), so faecal pellets of a

species with sexual weight dimorphism ($\overline{M}/\overline{F} \approx 2$) (Kirkpatrick, 1996) can be qualitatively classified into three categories based on their relative sizes: AMs (the biggest), AFs (moderate) and immatures (the smallest). Although *R. bieti* consists primarily of OMUs, there is at least one AMU including some adults and subadult males, and several juveniles (Kirkpatrick, 1996). Since OMUs and AMUs do not sleep together, it seems unlikely that pellets will be confused between sub-adult males and AFs, although they may have similar sized pellets and body weight. Moreover, the shape of AM and subadult male pellets is more irregular than that of AF pellets. Therefore, whether there are AF pellets or not was used to distinguish OMUs from AMUs. If there are AF pellets, the unit is an OMU; contrarily, it is an AMU. Moreover, we sampled feces of about ten days old from June to October and those of some 20 days old form November to April.

Total pellets under the sleeping trees used by the monkeys for two nights were counted for data analysis in each season. The number of sleeping trees/patches used by OMUs and AMUs and the amount of pellets were presented in Tab. 1.

Tab. 1 The number of sleeping trees/patches used for two nights by OMUs and AMU in a group of *Rhinopithecus bieti* and the amount of faeces sampled at Baima Snow Mountain in four different periods of 2000 – 2001

	Jun.		Sep.-Oct.		Nov.		Apr.	
	OMU	AMU	OMU	AMU	OMU	AMU	OMU	AMU
Sleeping trees/patches	37	8	23	21	36	16	33	6
Feces (pellets)	6 875		5 515		9 627		4 519	

OMU: one-male, multi-female unit; AMU: all-male unit.

1.4 Composition and size of study group

Data on group composition was collected using the rule that the distance between any two monkeys in an OMU is shorter than that from two adjacent OMUs when the group was crossing an open gully (20 m width) in Nov. 2001. Monkeys quickly traveled the gully in two parallel teams and the anterior individuals mingled together, so compositions of only 15 OMUs could entirely be recorded. Adult males (AMs) can be distinguished from AFs based on their body dimorphism (Kirkpatrick, 1996). Immatures clasping their mothers' bellies were regarded as infants, and other immature animals independently walking on the ground were considered as juveniles. Since individuals in the AMU were not observed, they were presumed to be at the front of the group. The distance between the group and the observer was about 600 m and angle of depression is approximately 3 – 5°.

Group size was 175 in 1994 (Kirkpatrick, 1996) and about 250 in 1998 (Maclennan, pers. comm.). So the population growth rate (r) can be estimated between the two periods (Eisenberg et al, 1981):

$$r = \frac{\ln 250 - \ln 175}{4} 0.09/(\text{individual} \cdot \text{year})$$

$$\lambda = e^{0.09} = 1.09/\text{year}$$

Assuming that r is invariable during the period from 1998 to 2001 and equal to that between 1994 and 1998, group size in 2001 can be estimated by its size in 1998 and r:

$$250 \times 1.09^3 = 324$$

1.5 Data process and analysis

It is essential to obtain the mean number of faeces produced per night (MnFN) by each animal of different age-sex classes to estimate group size and composition in terms of total pellets under sleeping trees. It is theoretically necessary to use the numbers of AMs and AFs in trees to make regression lines of their pellet amount, and then the slope of this regression line should be its MnFN. However, this requirement cannot actually be fulfilled, given that it is impossible to fully count monkeys in trees one by one at dusk due to the dense forests, low visibility and long distance. Thus, the numbers of AMs and AFs in OMUs counted by direct observation are used to plot regression lines. The process of plotting regression lines was as follows. First, though we have sampled 15 OMUs by direct observation and obtained the range of the number of their AFs (from three to eight), we can't exclude groups with less than three or more than eight AFs. So OMUs with an amount of AF pellets that indicate the number is within the range from thee to eight were chosen to make regression lines. Similarly, only OMUs with pellets showing the AM number is between one and two can be used. Secondly, mean numbers of AFs and AMs in OMUs were acquired by direct observation. We used the amount of pellets under trees and roughly estimated MnFN per individual to calculate mean numbers of AMs and AFs,

then compared them with those calculated by direct counting. If they didn't match with each other, the process was repeated through "trial and error" until they are the same. So the estimated MnFN per animal was obtained and used to divide the amount of pellets under trees, and then the trees under which the amount of faeces fulfilled the above mentioned requirements were chosen to plot regression lines. Thirdly, we ranked OMUs by size, and sleeping trees by the amount of faeces under them, and paired the ranks under the assumption that sleeping trees and OMUs with the same ranks had the same number of individuals. If the number of ranked OMUs was not a factor of the number of ranked sleeping trees, some OMUs of the given rank would be added according to their relative quantities in all sampled OMUs to make regression lines with the same number of ranked sleeping trees and ranked OMUs. In addition, MnFN per animal in AMUs was impossible to obtain due to no observation of them during the sampling. Therefore it is assumed to be equal to that per AM in OMUs. Group-size minus the amount of adults in OMUs and animals in AMUs is the total number of immatures in OMUs. Mean faecal number per immature was obtained by the amount of faeces divided by the total number of immatures. This is an approximate value because the number was under-counted due to poor visibility.

Since two OMUs sometimes sleep in one sleeping-tree cluster, and the number of OMUs estimated by faeces is greatest in spring compared with other seasons, data on faeces in spring were used to make population estimates. If a multi-female unit spends one night in one tree, and the number of AMs is ≥ 1.5 estimated by faeces, the unit is regarded as including two AMs; inversely, it is an OMU. Similarly, when the monkeys use a sleeping-tree cluster and the estimated number of AM is ≥ 1.5, it is difficult to distinguish two OMUs from a two-AMs multiple females unit. Other cases occur with lower probabilities.

Group size (G_s) can be estimated by MnFN per individual of different classes and the amount of their faeces at one sleeping site:

$$G_s = \frac{N_{ad} + N_{ia}}{M_a} + \frac{N_{af}}{M_f} + \frac{N_{im}}{M_i}$$

in which Nad expresses total pellets of AMs in OMUs, N_{ia} expresses total pellets of individuals in AMUs, N_{af} expresses total pellets of AFs in OMUs, N_{im} expresses total pellets of immatures in OMUs; M_a expresses MnFN per AM in OMUs or animal in AMU, M_f expresses MnFN per AF, M_i expresses MnFN per immature.

2 Results

Composition of OMUs in the band of *R. bieti* is presented in Tab. 2. One male units constitute 93.3% (14/15) of all units observed. Since the numbers of AMs and AFs in OMUs correlate significantly with their pellet amounts in each season MnFN per AM and AF respectively is the slope of their regression line (Fig. 1). Mean faecal number per immature is 7.7 in spring, 7.7 in summer, 14.9 in autumn and 5.3 in winter.

Group composition is presented in Tab. 3, which is estimated by faeces at two sleeping sites. Faeces analysis indicates that the number of OMUs in the group is about 20 – 21, which includes two cases where two OMUs used one sleeping-tree patch. OMUs constitute 91.9% of all units. The AMU accounts for 8.1% of the group composition. The accuracy of estimating mean AFs in terms of faeces is about 90.6%, that is, the deviation is some 9.4% [(5.8 – 5.3)/5.3].

3 Discussion

In comparison with using monkeys' activities and tracks to roughly estimate group sizes (Long et al, 1996), the use of faecal sampling under sleeping trees to make population estimates is a relatively reliable and convenient method under these conditions: the habitat terrain of the area is characterized by steep slopes and deep gorges, it is habitat that is snow-covered for 4 to 6

Tab. 2 Estimated composition [mean ± *SD* (range), sum] of multiple female units in a group of *Rhinopithecus bieti* when crossing an gully at Baima Snow Mountain in November 2001[1]

	Adult male	Adult female	Juvenile[2]	Infant[3]	Size of units	No. of units
Mean	1.1 ± 0.3	5.3 ± 2.0	2.5 ± 1.8	1.3 ± 1.6	10.1 ± 3.7	15
Range	1 – 2	3 – 8	1 – 8	0 – 6	5 – 17	
Sum	16	79	37	19	151	

[1] The number of multi-female, two-male unit constitutes 6.7% (1/15) of all units.

[2] Some juveniles that traveled together in a cohort were not observed.

[3] Infants on their mothers' bellies might be under-counted due to a distance of about 600 m and angle of depression of some 5° between the band and the observer.

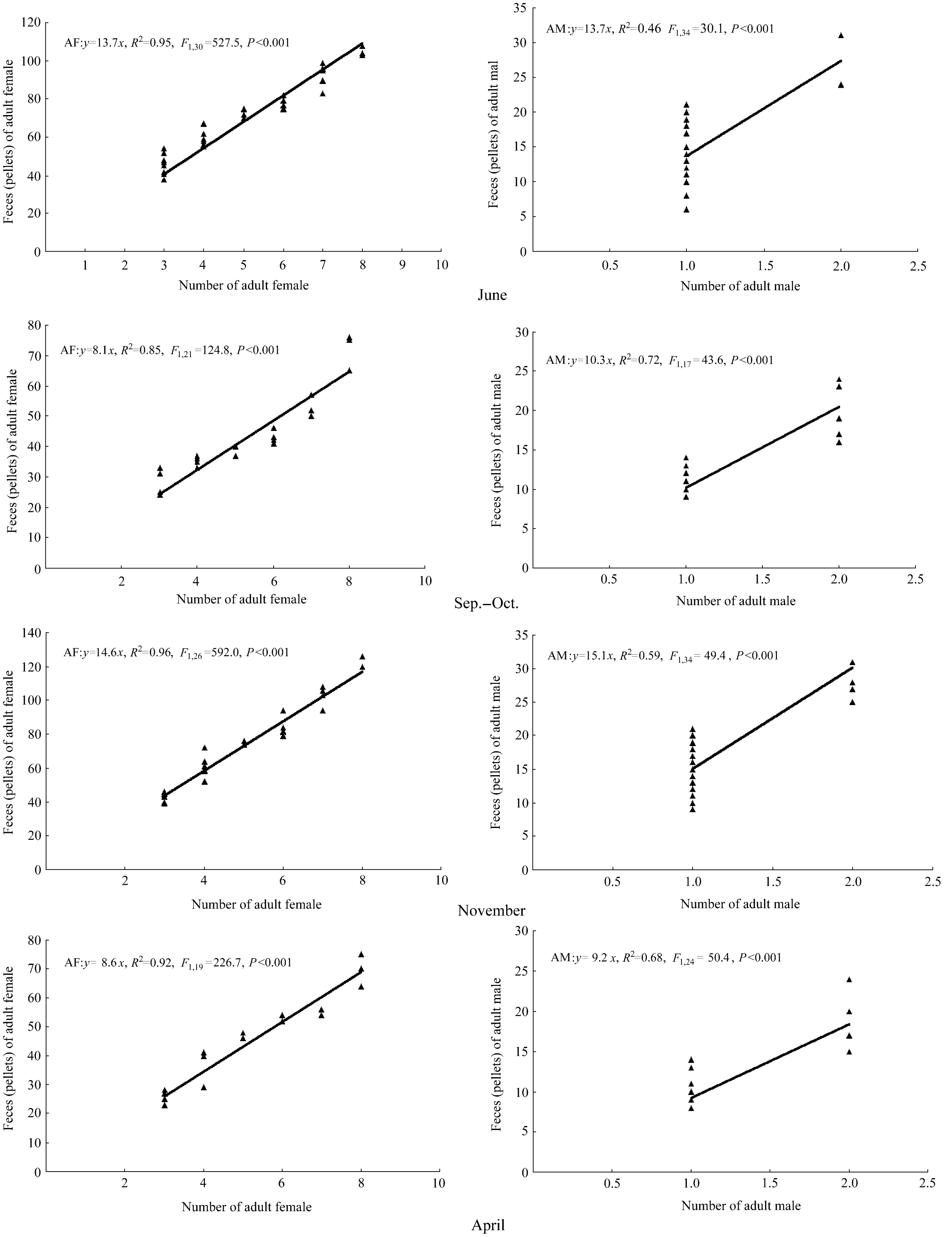

Fig. 1　Regression lines between the number of adult male and adult female *Rhinopithecus bieti* in OMUs and their faeces-amount (pellets) under sleeping trees in four different periods of 2000 – 2001. The slope of the regression line is the mean number of feces produced per night per individual.

Tab. 3 Composition [mean ± *SD* (range), sum] of a group of *Rhinopithecus bieti* estimated by faeces under sleeping trees used for two nights at Baima Snow Mountain in June 2001[1]

	AM	AF	Immature	Totals[2]	No. of STP	AM:AF	AMF:IM
OMU	1.1 ± 0.4	5.8 ± 2.9	8.9 ± 5.2	15.8 ± 7.3	37	1.0:5.1	1.0:1.3
	0.4 – 2.8	2.3 – 15.6	1.9 – 20.9	7.2 – 30.8			
	21.0	106.5	164.5	292.0			
AMU	1.5 ± 1.1	–	6.3 ± 3.2	7.7 ± 3.0	8	–	1.0:4.2
	0.0 – 2.7	–	2.6 – 11.9	5.0 – 13.2			
	6.0	–	25.0	31.0			

[1] AM: adult male; AF: adult female; IM = immature; AMF: adult males and females in one-male, multi-female units; STP: sleeping trees/patches; AMU: all-male unit; two-adult male units constitute 8.1% (3/37) of all units.

[2] Maximum size of the unit is the combination of two OMUs using one sleeping-tree patch.

months, and monkeys are difficult to spot and shy of humans. On the other hand, the accuracy of the method is about 90.6% from the viewpoint of mean females in OMUs. It is presumed that there may be several elements that caused this bias. Firstly, although faeces were carefully located to avoid high variance in the completeness of collection under trees, it seemed unlikely to have the same chance to finding them under each tree due to the influence of weeds, shrubs and hugger-mugger fallen branches.

Secondly, as faeces fall through tree crowns, the majority of pellets fall and concentrate around the trunks of trees. However some hit branches and fall within a radius of 2.5 m from the trunk. This may affect accurate counting of pellets.

Thirdly, *R. bieti* has sexual weight dimorphism (Kirkpatrick, 1996) and pellet sizes of captive monkeys positively relate to their body sizes (Zhao et al, 1988). Although the majority of pellets from AMs can be distinguished from those of AFs, it is presumed that there may be some confusion between the smallest pellets of AMs and the largest ones of AFs. Moreover, adult males *R. bieti* in captive OMUs usually attack their offspring (≥ 3 yr and housed in another cage) (Cui et al, 2006b), so large juveniles were conjectured to be outside of OMUs. However, it was difficult to completely avoid confusion between pellets of large juveniles and small females.

Fourthly, if the rate of producing faeces changes with individuals of the same sex-age class, it will have some influence on the accuracy of this method. The variance in the amount of faeces produced by each AM per night may stem from a different rates of faecal production, but different rates of AFs may be counteracted by more AFs in OMUs (Fig. 1).

Mean faecal number per AM and AF is basically similar with each other in each season, but they change with seasons. This maybe in relation to differing diets. Moreover, MnFN per immature is not close to its actual number but only a relative value.

It will be better to use faeces as fresh as possible to make population estimates since they may be decomposed by insects in spring and summer. However, they may remain on the forest floor for a long period in autumn and winter. In general, so long as pellets don't change their sizes, they can be used to make population estimates.

When two multi-female units spend nights in a sleeping-tree patch and the number of AMs is ≥ 1.5 estimated by faeces, the challenge of distinguishing two OMUs from a two-AM unit should be resolved by other means in future research. From north to south, the altitude of habitat for the species decreases; its habitat type changes from fir forests (Kirkpatrick, 1996) to mixed coniferous and broadleaf forests (Ding, 2003; Liu, 2003). Its main food changes accordingly from lichens (Kirkpatrick, 1996) to deciduous broadleaves (Ding, 2003), and to bamboo leaves (Yang & Zhao, 2001). Thus, MnFN per individual may vary with its main food; therefore this method can only be applied to groups, whose habitat and main food are similar to those of this study group.

The percentage of OMUs in the group (93.2% for direct count and 91.9% for faecal estimate) is inconsistent with the previous report of 100% (Kirkpatrick, 1996). It varied with groups in *R. roxellana*, ranging from 77% – 100% (Ren et al, 1998), and with species of Colobine from 66% to 100% (Newton & Dunbar, 1994).

Mean OMU-size was approximately 16 when estimated by faeces, which may deviate from its real value since the number of immatures estimated by faeces could not be match with that calculated by direct count. The maximum size of the unit is the combination of two

OMUs using one sleeping-tree patch.

The percentage of the AMU-size in the group varies with species and groups of the same species of Colobines. AMUs of *R. bieti* included 13 – 15 animals, constituting 7.4 – 8.6% of the group (Kirkpatrick, 1996). In this study, the percent is about 9.6% estimated by faeces. It was 15.6% in *Presbytis entellus* (Newton, 1987) and 13.1% in *Nasalis larvatus* (Yeager, 1990). However, it changed with groups in *R. roxellana*, ranging from 5.8% to 27.3% (Ren et al, 1998).

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